A COMPARISON OF AMBIENT AIR POLLUTANTS AT JOHN F. KENNEDY SPACE CENTER WITH DATA FROM THE FLORIDA STATEWIDE MONITORING NETWORK (1983-1986)

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ABSTRACT

Monitoring of Environmental Protection Agency criteria air pollutants at John F. Kennedy Space Center (KSC) on north Merritt Island, Florida has been conducted since January 1983 as part of the Long-term Environmental Monitoring Program for the NASA Biomedical Operations and Research Office. Data were collected to evaluate trends in air pollutant concentrations and potential impacts of KSC operations on air quality. Continuous analyzers were operated for ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and the following meteorological parameters: wind direction and speed, temperature, and relative humidity. A Sierra-Anderson inhalable particulate monitor (PM_{10}) was operated for a 24-hour period every six days. Instrumentation was calibrated in accordance with the Quality Assurance Plan of the Florida Department of Environmental Regulation. Independent audits were also performed two or three times per year. Data from 1983 through 1986 showed a decrease in the 24-hour SO_2 averages each year. In addition, the highest 24-hour SO_2 average level each year was higher than those in all other locations on the east coast of Florida except in Duval and Nassau counties. However, the second highest 24-hour average SO_2 levels were lower than the statewide nine-station averages reported for each year except 1983. The NO_2 annual averages at KSC were much lower than the statewide nine-station averages that ranged between 24.5 to 28.7 ug/m^3. There was a slight increase each year at KSC from 3.3 ug/m^3 in 1983 to 4.6 ug/m^3 by 1986. The CO annual averages, second highest eight-hour, and one-hour averages were lower than the statewide averages for micro-scale, middle-scale, and neighborhood scale. The pollutant of most concern at KSC is ozone, because it has been shown to be consistently high compared to the federal and state standard of 120 ppb maximum one-hour average and it has increased yearly (98, 101, 103, 109 ppb). These values, as compared to six county averages, are 84.6 percent, 94.0 percent, 92.2 percent, and 98.1 percent, respectively. The percentage of daily maximum one-hour O_3 averages greater than 90 ppb at KSC was higher than Duval, Broward, Dade, and Palm Beach counties in 1984 and 1985 and Orange County in 1983 and 1985. In conclusion, the overall air quality at KSC is good, but future regional development may have an impact and monitoring at KSC will be continued.

INTRODUCTION

Monitoring of Environmental Protection Agency (EPA) criteria air pollutants at John F. Kennedy Space Center (KSC) on north Merritt Island, Florida, has been conducted since January 1983 as part of the Long-term Environmental Monitoring Program for the KSC Biomedical Operations and Research Office. This program includes activities in areas such as air quality, surface and groundwater quality, threatened and endangered species, vegetation communities, soil chemistry, rain volume, rain chemistry, and launch operations effects.

Since KSC is classified as a Prevention of Significant Deterioration (PSD) attainment area for all of the criteria pollutants, data are collected to evaluate trends in air pollutant concentrations and any potential impacts on air quality from KSC operations on an urban scale (4-50 km). Daily air quality levels are influenced primarily by vehicular traffic, utilities fuel combustion, standard refurbishment and maintenance operations, incinerator operations, and emissions from two regional power plants which are located approximately six km to the southwest from the permanent air monitoring station A (PAMS A)[1]. Space Shuttle launches, training fires, and prescribed burning on Merritt Island National Wildlife Refuge influence air quality as episodic events.

The Florida statewide air quality monitoring program provides the public and government with the identification of (1) areas where the ambient air quality standards are being violated, and (2) areas where the ambient standards are being met and for which plans are needed to ensure maintenance of acceptable levels of air quality in the face of anticipated population and industrial growth[2].

The purpose of this paper was to compare ambient air quality data collected at KSC with Florida statewide data to determine relationships between levels and trends for the two data sets.

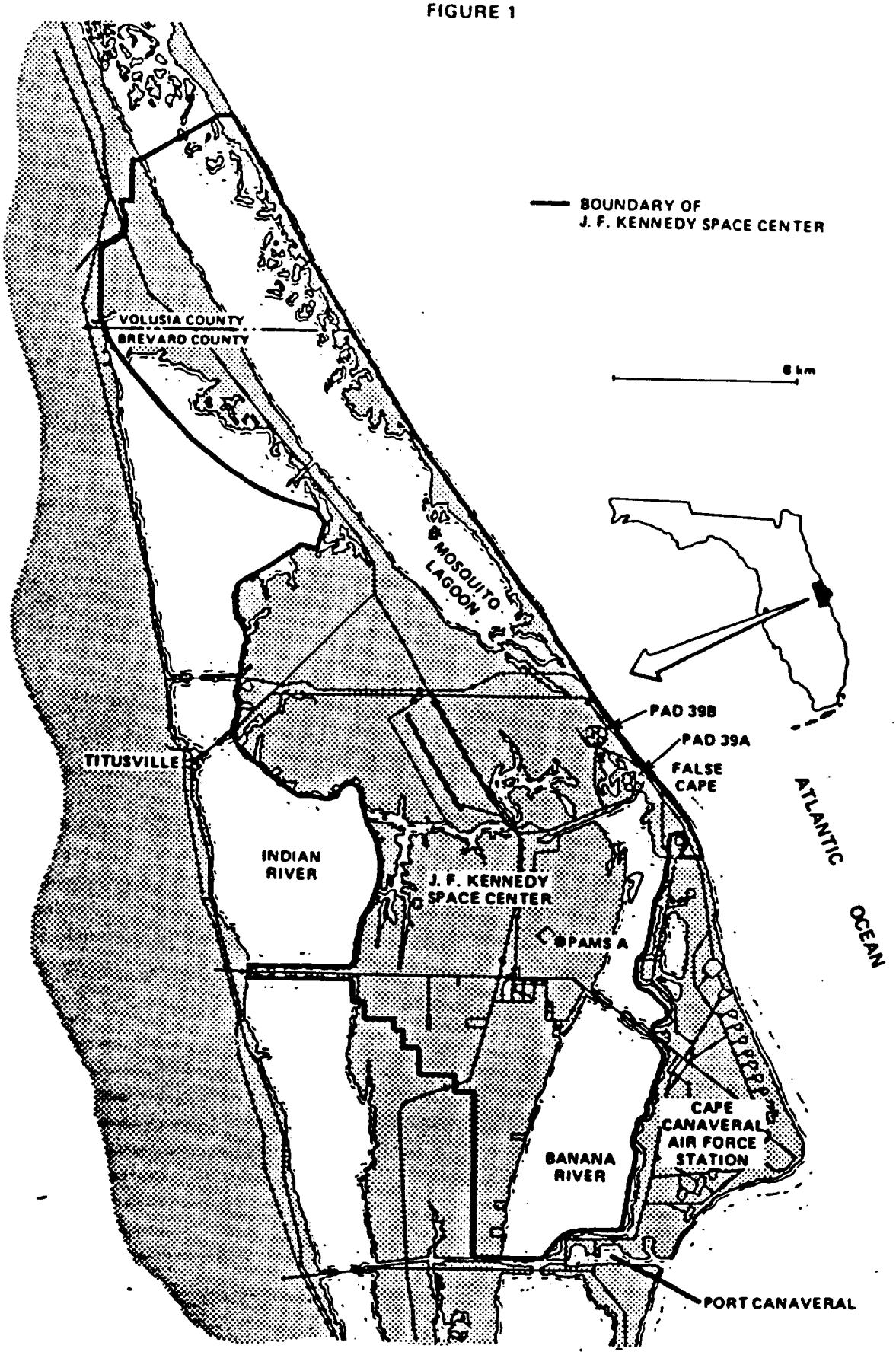
METHODS

KSC data were collected at a permanent air monitoring station (PAMS A) which is an 8x8x16 foot trailer configured to monitor the following parameters: ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), wind speed, wind azimuth, temperature, relative humidity, and inhalable particulates (PM_{10}). Data are collected continuously on a per minute basis and stored on a Hewlett Packard 1000 series computer. PAMS A is located at the Central Instrumentation Facility (CIF) antenna site, one mile to the north of the KSC Headquarters Industrial area and the NASA Causeway (Figure 1).

Other potential emissions and particulate sources are located, in relation to the sampling site, as follows: the Atlantic Ocean is 4.8 miles due east, Cape Canaveral Air Force Station is 4.8 miles to the southeast, Port Canaveral is 8.8 miles to the south-southeast, the city of Cocoa is 11.4 miles to the southwest, two oil-fired power plants are 9.0 miles to the west-southwest, the Vehicle Assembly Building Industrial Area is 3.2 miles to the north, and launch pads 39A and 39B are approximately 5.3 miles to the northeast.

All continuous gas analyzers were subjected to Florida Department of Environmental Regulation (FDER) Quality Assurance Guidelines consisting of routine bi-weekly precision and Level 1 checks, as well as multipoint calibrations either quarterly or after instrument repairs. Independent audits were performed two to three times per year on the gas analyzers, the particulate sampler (PM_{10}), and the meteorological sensors[3]. Data analyses and statistical analyses (alpha=0.05) were conducted with SAS on an IBM PCAT.

FIGURE 1


BOUNDARY OF
J. F. KENNEDY SPACE CENTER
VOLUSIA COUNTY
BREVARD COUNTY
6 km
N
MOSQUITO LAGOON
PAD 39B
PAD 39A
FALSE CAPE
TITUSVILLE
INDIAN RIVER
J. F. KENNEDY SPACE CENTER
PAMS A
ATLANTIC OCEAN
CAPE CANAVERAL AIR FORCE STATION
BANANA RIVER
PORT CANAVERAL

The Florida air quality monitoring network consists of approximately 300 monitors located in 35 counties throughout the state[2]. The data used in this paper were obtained from the 1985 Ambient Air Quality in Florida report. The raw O_3 data for 1986 was obtained from Mr. Brian Kerchoff of FDER.

RESULTS AND DISCUSSION

Monthly maximum 24-hour KSC SO_2 averages have decreased each year from 1983 through 1986 (Figure 2). The highest 24-hour SO_2 average each year was higher than values for all other locations on the east coast of Florida except Duvall and Nassau counties[1]. This was possibly caused by a downwash plume from the two oil-fired power plants on the Indian River to the southwest. The second highest 24-hour average SO_2 levels (regulatory values) were lower than the reported statewide nine-station composite averages for each year except 1983 (Figure 3). The KSC data show a decreasing trend in 1983 and 1984 with a leveling off in 1985 and 1986. In comparison, there was no clear statewide trend as values dropped from 1983 to 1985 and then increased in 1986. Since the KSC values of SO_2 are lower than the state values and are decreasing, air quality (in terms of SO_2) at KSC is good.

Monthly maximum KSC one-hour NO_2 averages decreased slightly each year from 1983 through 1986 (Figure 4). The highest KSC NO_2 one-hour average of 58 ppb (116 ug/m^3) occurred on January 3, 1985 with a wind direction average of 232 degrees, which is where the two oil--fired power plants are located. Other high values occurred in September, 1985 (43 ppb/86 ug/m^3) and July, 1986 (32 ppb/64 ug/m^3). There was no information available on maximum one-hour NO_2 state values from the 1985 state report.

The KSC NO_2 annual averages displayed a slight increasing trend from 3.3 ug/m^3 in 1983 to 4.6 ug/m^3 in 1986 (Figure 5). These values were much lower than the statewide nine-station composite average values of 28 ug/m^3. The statewide values display no trend towards increasing or decreasing NO_2 concentrations[2]. The highest NO_2 annual average recorded in the state in 1985 was 54 ug/m^3 in Tampa and the highest concentration recorded in 1984 was 56 ug/m^3, also in Tampa. Since the KSC NO_2 annual averages are much lower than the state values, air quality (in terms of NO_2) at KSC is good.

Monthly maximum one-hour KSC carbon monoxide (CO) averages display a slight decreasing trend (Figure 6). A comparison of KSC CO annual averages, second highest one-hour averages, and second highest eight-hour averages with statewide values on a micro-scale, middle-scale, and a neighborhood scale shows that the KSC values were lower in all cases except for the annual average of 1983 when the KSC value was greater than the statewide neighborhood scale (Figure 7). The occurrence was caused by a controlled burn by the U.S. Fish and Wildlife Service at Merritt Island Wildlife Refuge. The state values for 1986 annual averages were not yet available.

Monthly means (1983-1986) of inhalable particulates (PM_{10}) showed highest values in April, July, August, September, and November, reflecting a bi-annual peak pattern (Figure 8). June, July, and October means included the highest values of 122, 100, and 150 ug/m^3, respectively. Because of the large range of values in January, July, August, and November, the 95 percent confidence intervals were too large to ascertain any clear statistical differences between any of the monthly mean values. The values ranged from 2.9 ug/m^3 to 150.1 ug/m^3 with an overall mean and standard deviation of 25.89 ug/m^3 and 18.50 ug/m^3, respectively. The 95 percent confidence intervals were $\pm$2.68 ug/m^3.

FIGURE 2

ANNUAL SULFUR DIOXIDE (1983–1986) AT KSC

MONTHLY MAXIMUM 24–HOUR AVERAGES

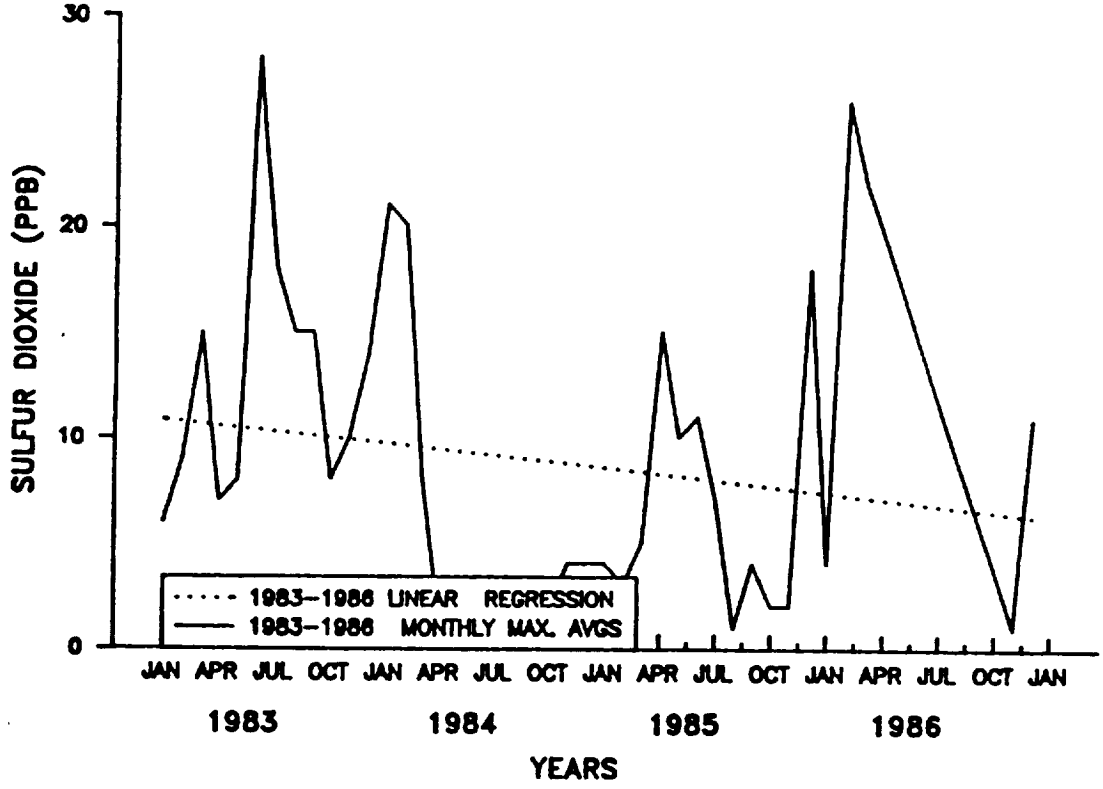


FIGURE 3

NINE STATION COMPOSITE

2ND HIGHEST 24–HOUR

AVERAGE SO2 VS. KSC

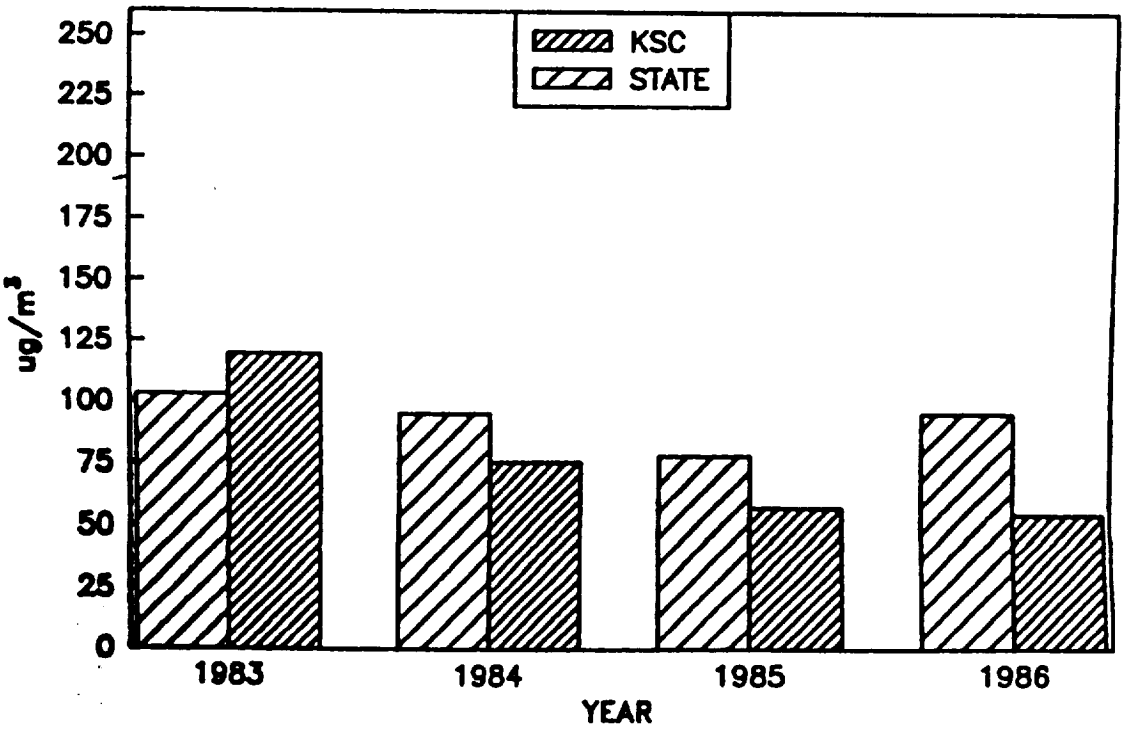


FIGURE 4
ANNUAL NITROGEN DIOXIDE (1983–1986) AT KSC
MONTHLY MAXIMUM 1-HOUR AVERAGES

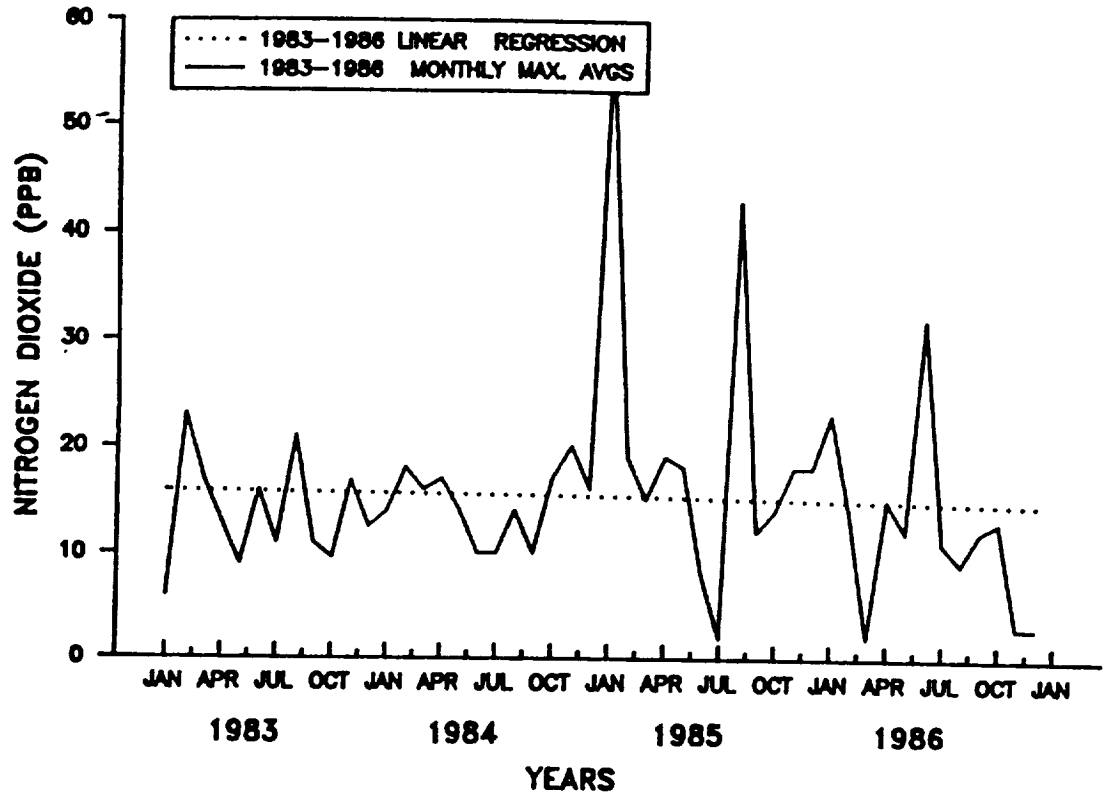


FIGURE 5
NITROGEN DIOXIDE
NINE STATION COMPOSITE
ANNUAL AVERAGE VS. KSC

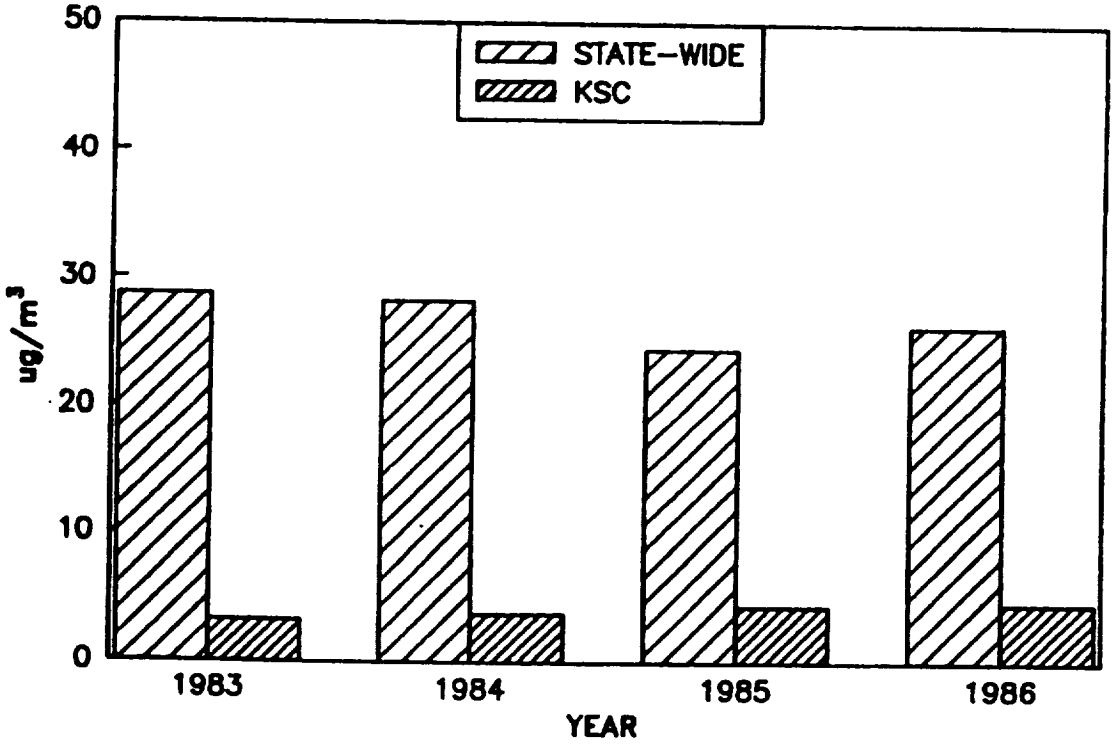


FIGURE 6
ANNUAL CARBON MONOXIDE (1983–1986) AT KSC

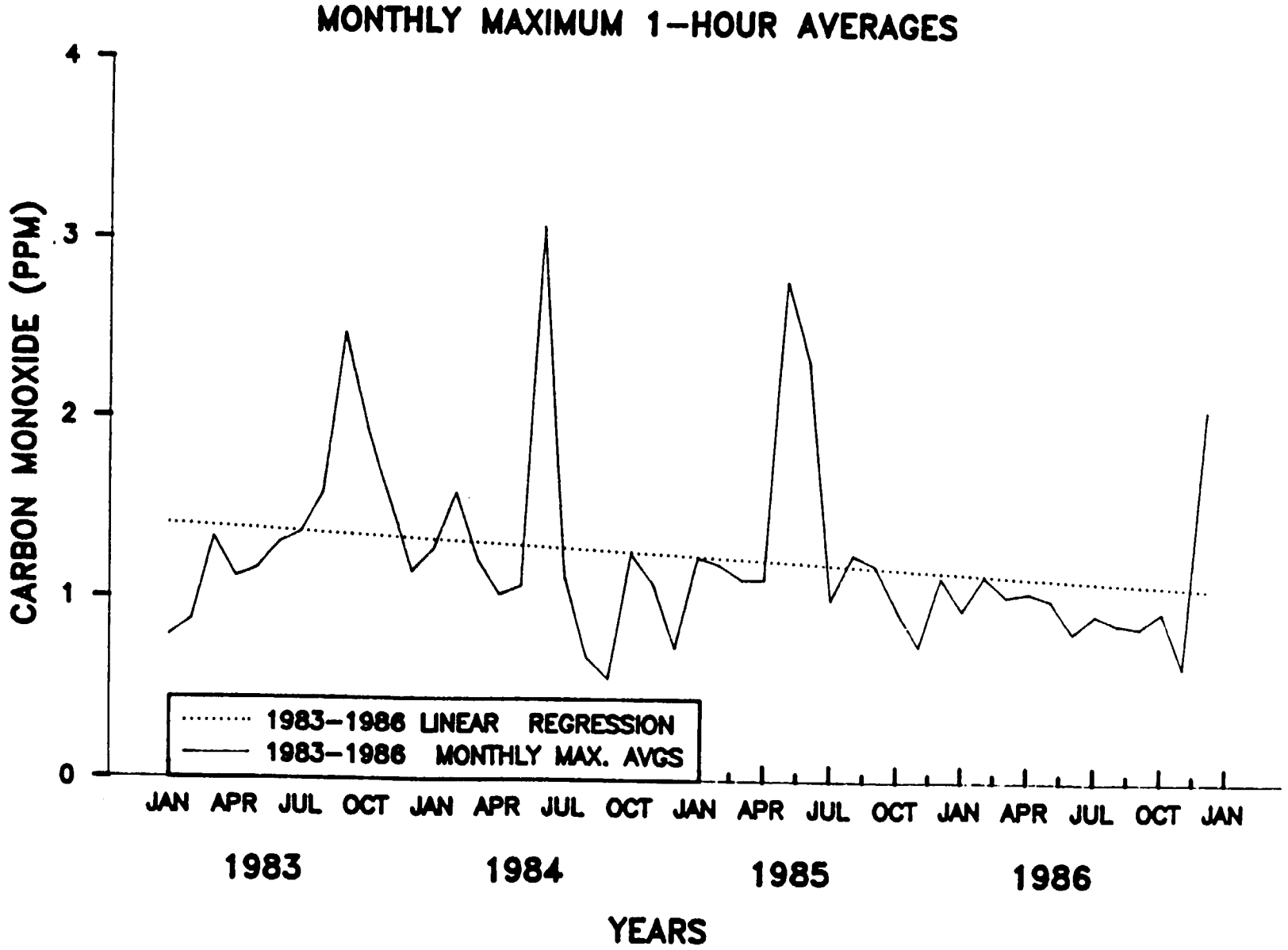
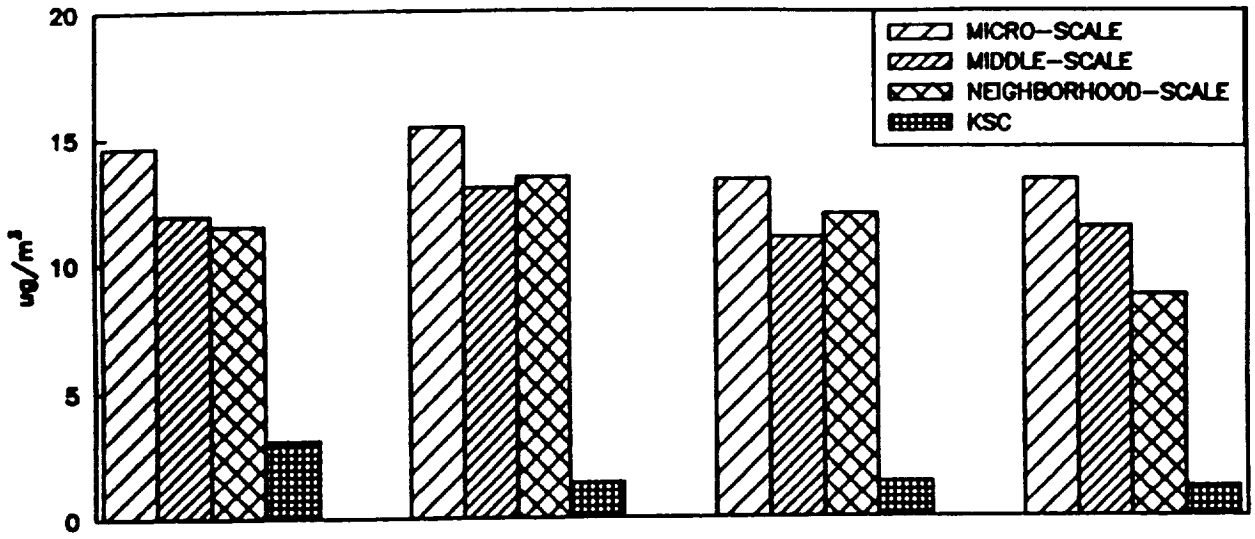
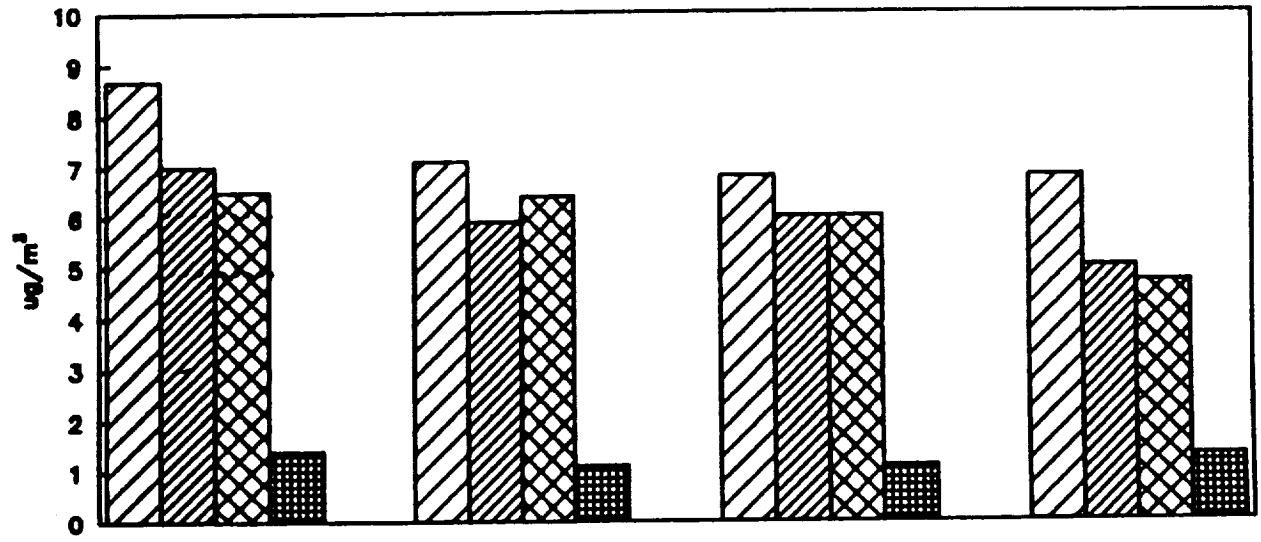


FIGURE 7
KSC VS. STATEWIDE
2ND HIGHEST 1-HOUR CARBON
MONOXIDE AVERAGES



2ND HIGHEST 8-HOUR CO MONOXIDE



ANNUAL CARBON MONOXIDE AVERAGES

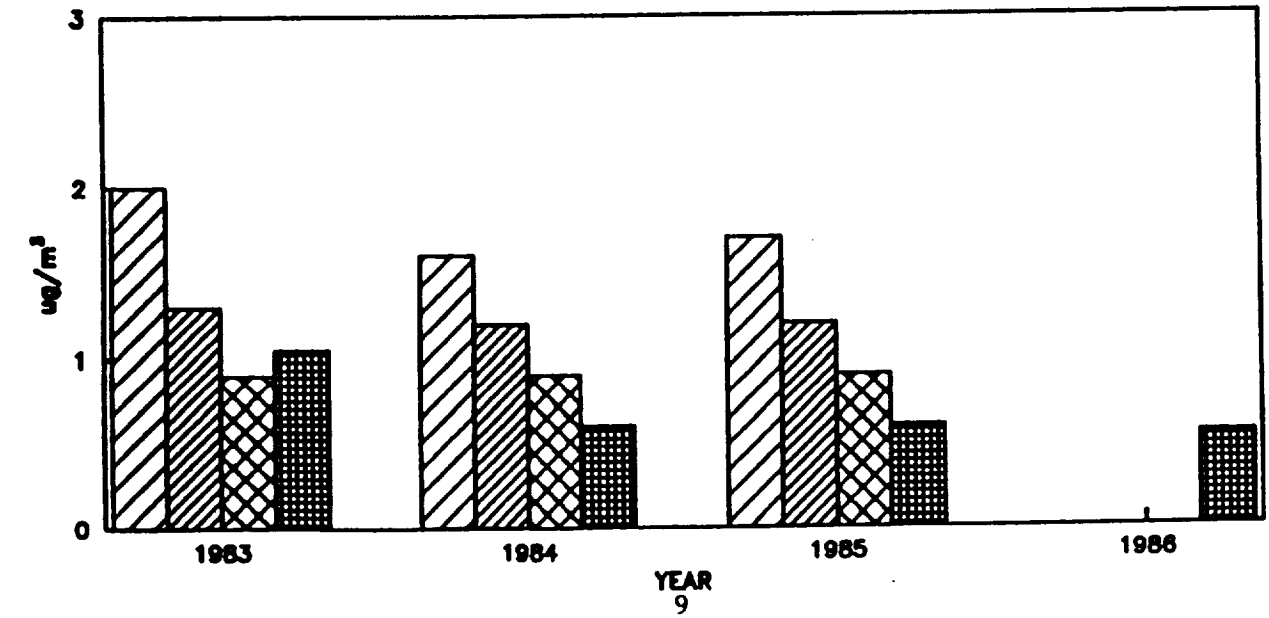
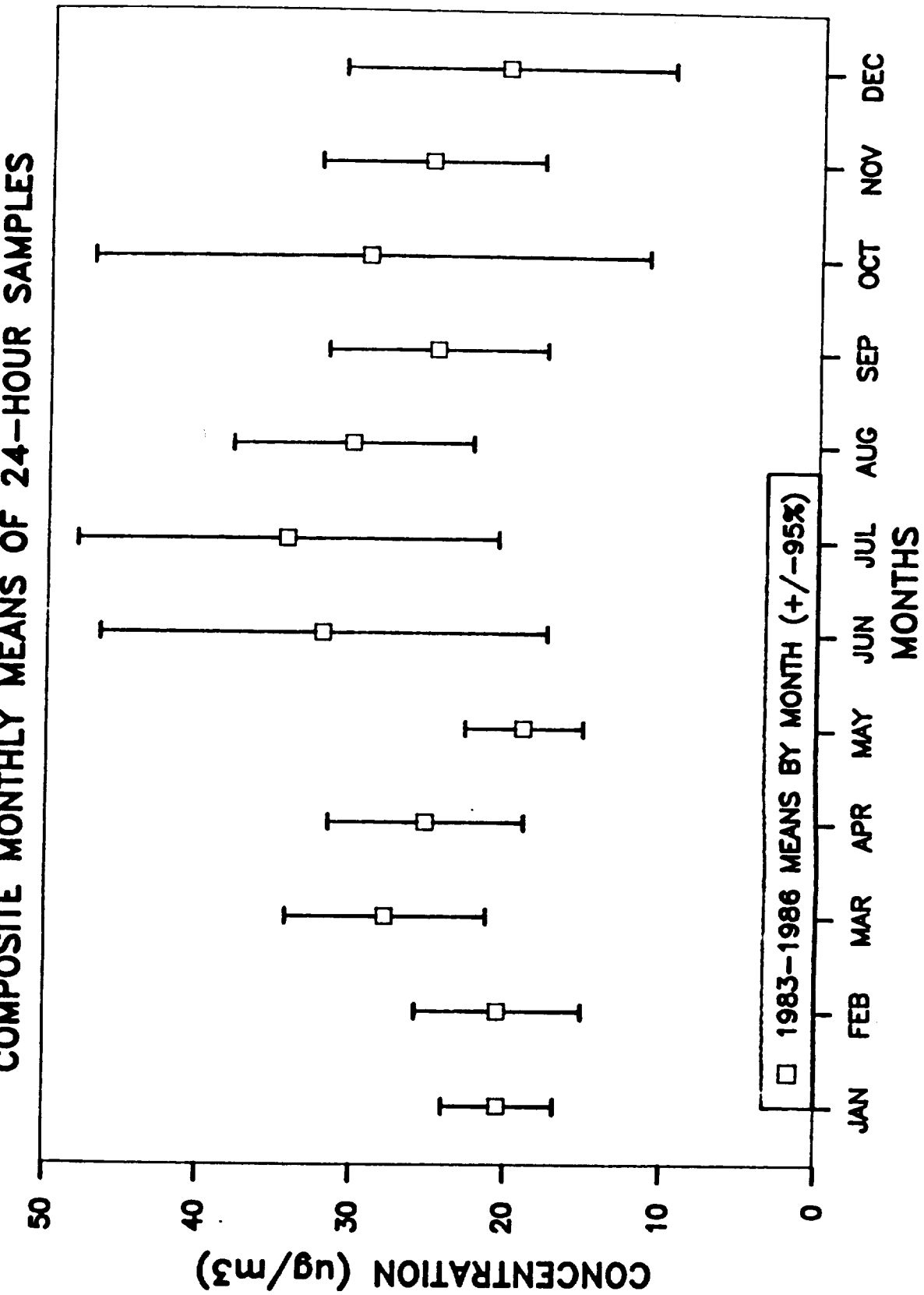


FIGURE 8

ANNUAL INHALABLE (PM-10) PARTICULATES (1983-1986) AT KSC
COMPOSITE MONTHLY MEANS OF 24-HOUR SAMPLES



There were no state values for PM_{10} particulates for a direct comparison but the following relationship between TSP and PM_{10} was recently reported: 500 ug/m^3 (TSP) approximately equals 150 ug/m^3 (PM_{10})[4]. On this basis, the KSC mean of 25.89 ug/m^3 (PM_{10}) would be similar to 86.3 ug/m^3 (TSP) which is 38 percent higher than the highest 24-hour average value from Brevard County which was 62.7 ug/m^3.

Ozone at KSC is consistently high compared to the federal and state standard of 120 ppb maximum one hour average and has increased yearly (98, 101, 103, 109 ppb). The increasing trend can be seen in Figure 9 which displays the monthly maximum averages (increasing trend) and monthly means (decreasing trend). The highest annual O_3 mean occurred in 1985 followed by a drop to the lowest value in 1986.

Bi-annual peaks occur in a four year composite of monthly means in April through June and October through November (Figure 10). Lower values July through September are due to reduced insolation, more cumulous clouds, numerous afternoon thunderstorms, and more active vertical mixing and dispersion[5]. Levels in July, August, and September were significantly (alpha=0.05) lower than February, April, May, and June.

The percentage of days with maximum one-hour averages greater than 90 ppb (high ozone) at KSC ranked highest in 1984 and 1985 and lowest in 1986 compared to seven statewide sites with the following percentages: 1983 (37.5 percent), 1984 (62.5 percent), 1985 (62.5 percent), and 1986 (12.5 percent) (Figure 11). The KSC values were higher than Orange County values two of four years and Palm Beach County values three of the four years . Maximum one-hour O_3 concentrations (regulatory values) at KSC ranked in increasing order compared to the seven statewide maximum values as follows: 1983 (25.0 percent), 1984 (37.5 percent), 1985 (50.0 percent), and 1986 (50.0 percent) (Figure 12). This plot also shows that the KSC O_3 one-hour averages have increased each year.

Further analyses were performed on the KSC O_3 data to investigate possible contributions by KSC operations. First, a pollution rose was generated (Figure 13) which showed that the highest frequency of winds during maximum one hour O_3 concentrations was from the east-south-southeast. The highest concentrations were from the west (WNW-WSW). There were no significant differences between months of the year, weekdays versus weekends, or wind directions as indicated by analysis of variance. The highest mean concentrations were from the west and the lowest mean concentrations were

from the southwest which is where the two oil-fired power plants are located (Figure 14). In addition, Figure 14 showed that there were no significant

differences between weekdays and weekends for the different wind direction classes (Figure 14). This would indicate that KSC daily operations (weekdays) are not causing higher O_3 levels at KSC.

In Florida, a near linear relationship between NO_2 and O_3 concentrations exists[5]. However for KSC data, a weak correlation of 0.2181 was found. Statistical analysis showed that NO_2 was not significantly different between years but was significantly different between months. Multiple comparisons showed that the month of January had a significantly higher NO_2 average than the remaining months. Also, weekdays had significantly higher average NO_2 values than the weekends. These significant differences are contrary to the statistical results obtained from the O_3 analysis and helps to explain the low correlation mentioned previously. As with O_3, there was no significant difference between the wind direction on the variable NO_2.

FIGURE 9

ANNUAL OZONE (1983–1986) AT KSC

MONTHLY MAXIMUM 1–HOUR AVERAGES

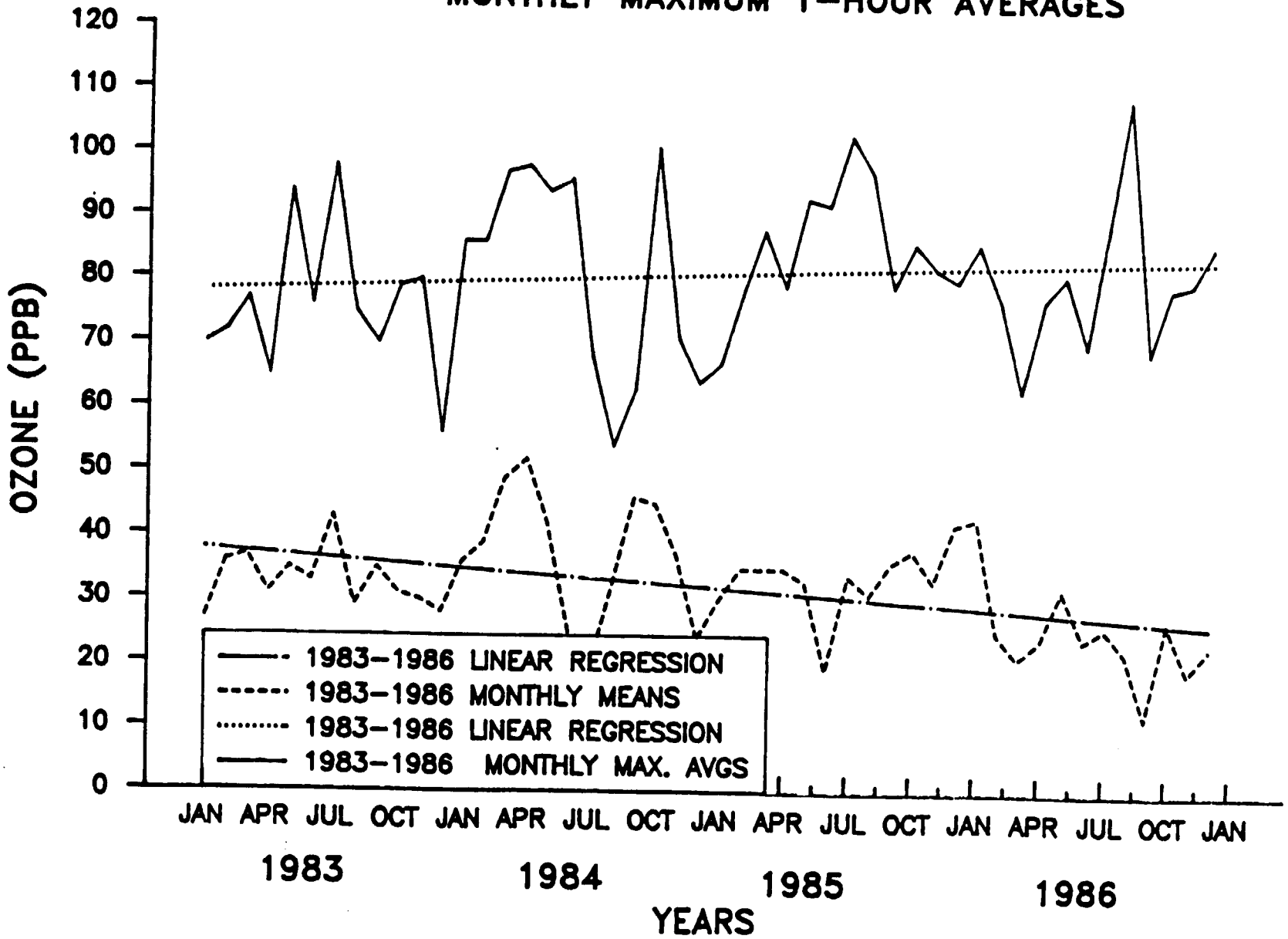


FIGURE 10

ANNUAL OZONE (1983–1986) AT KSC

MEANS OF 1-HOUR AVERAGES BY MONTH

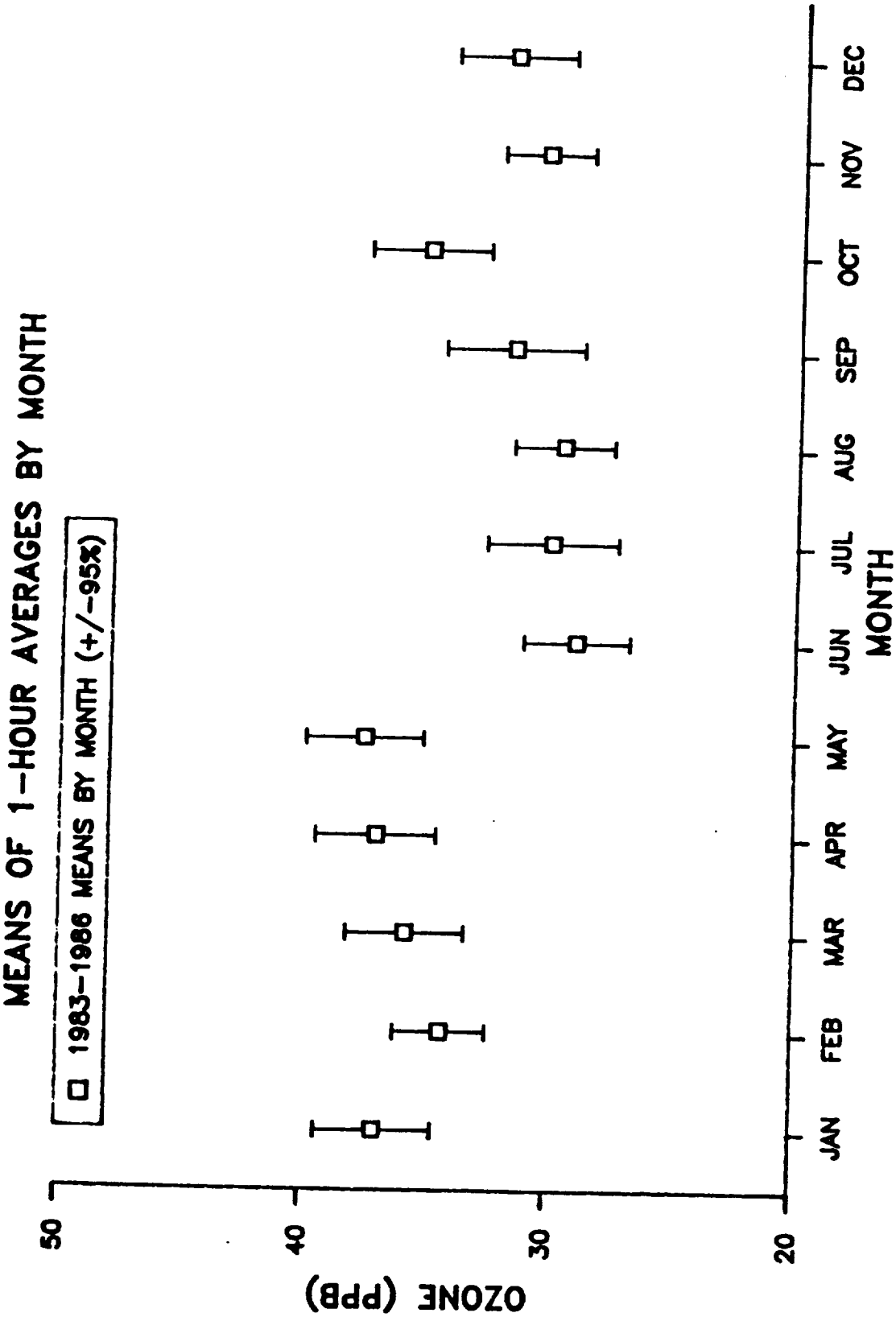


FIGURE 11
COMPARISON OF PERCENTAGE OF DAYS WITH MAX. HOURS > 90 PPB OF OZONE AT KSC WITH STATE-WIDE SITES

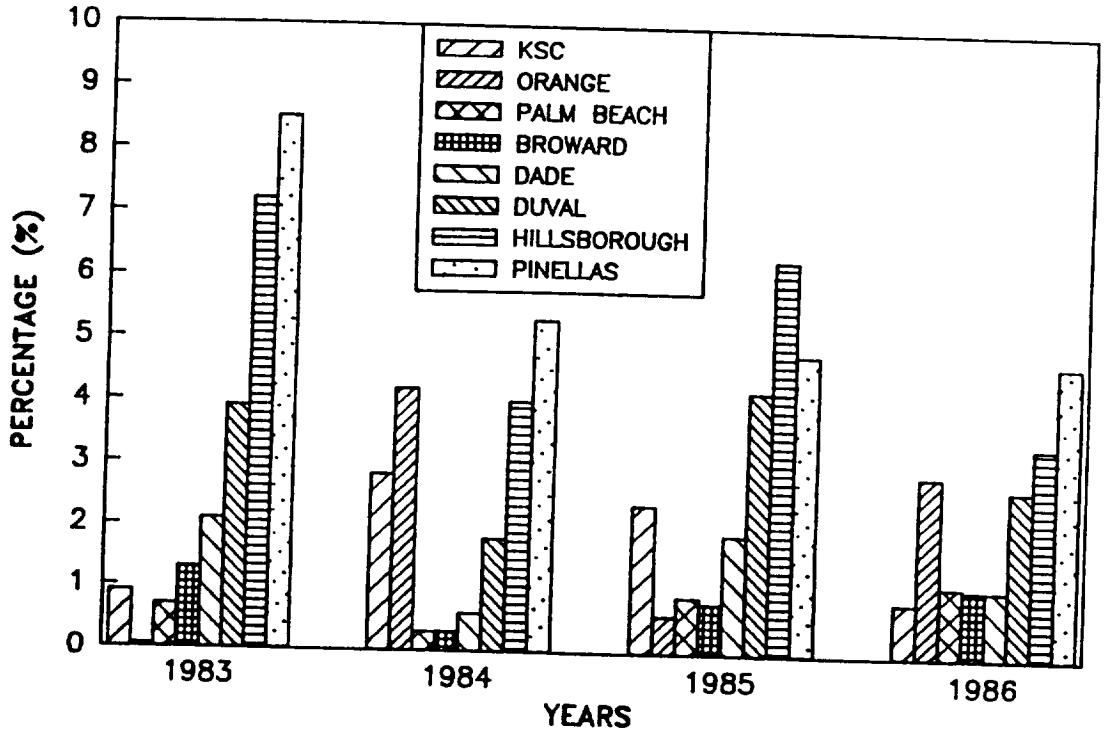


FIGURE 12
COMPARISON OF MAX. ONE-HOUR O3 CONCENTRATIONS AT KSC WITH STATE-WIDE SITES

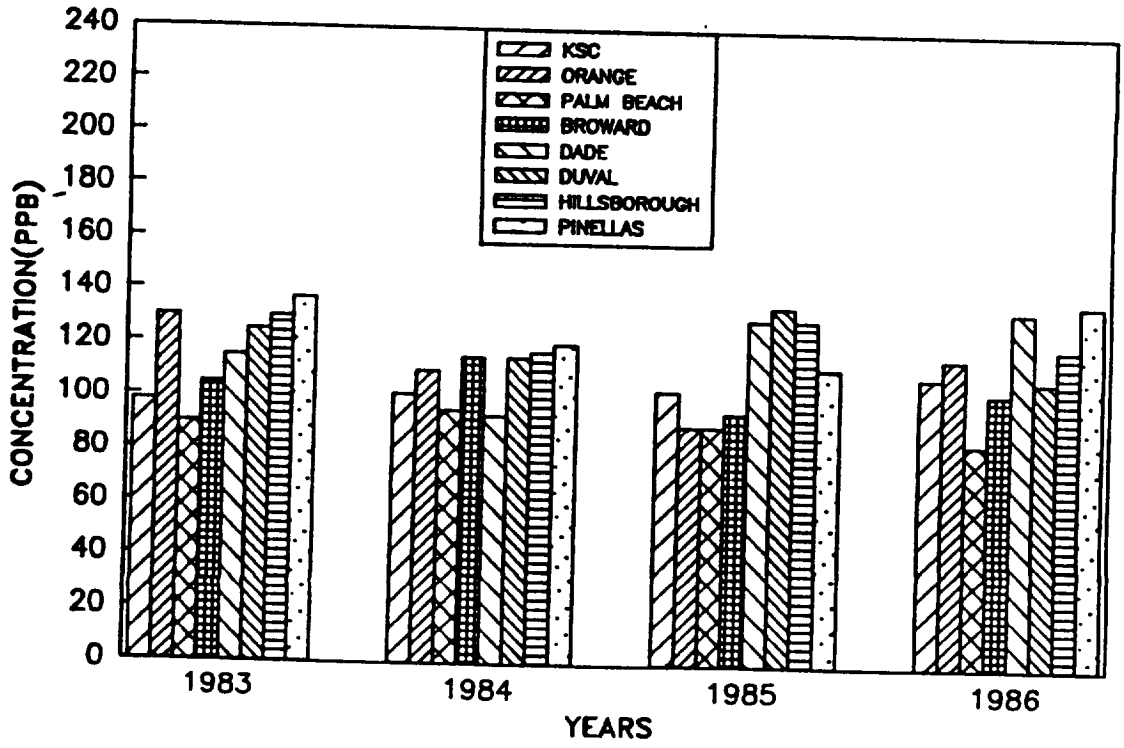


FIGURE 13

FOUR YEAR MAXIMUM 1-HOUR OZONE POLLUTION ROSE (1983-1986)

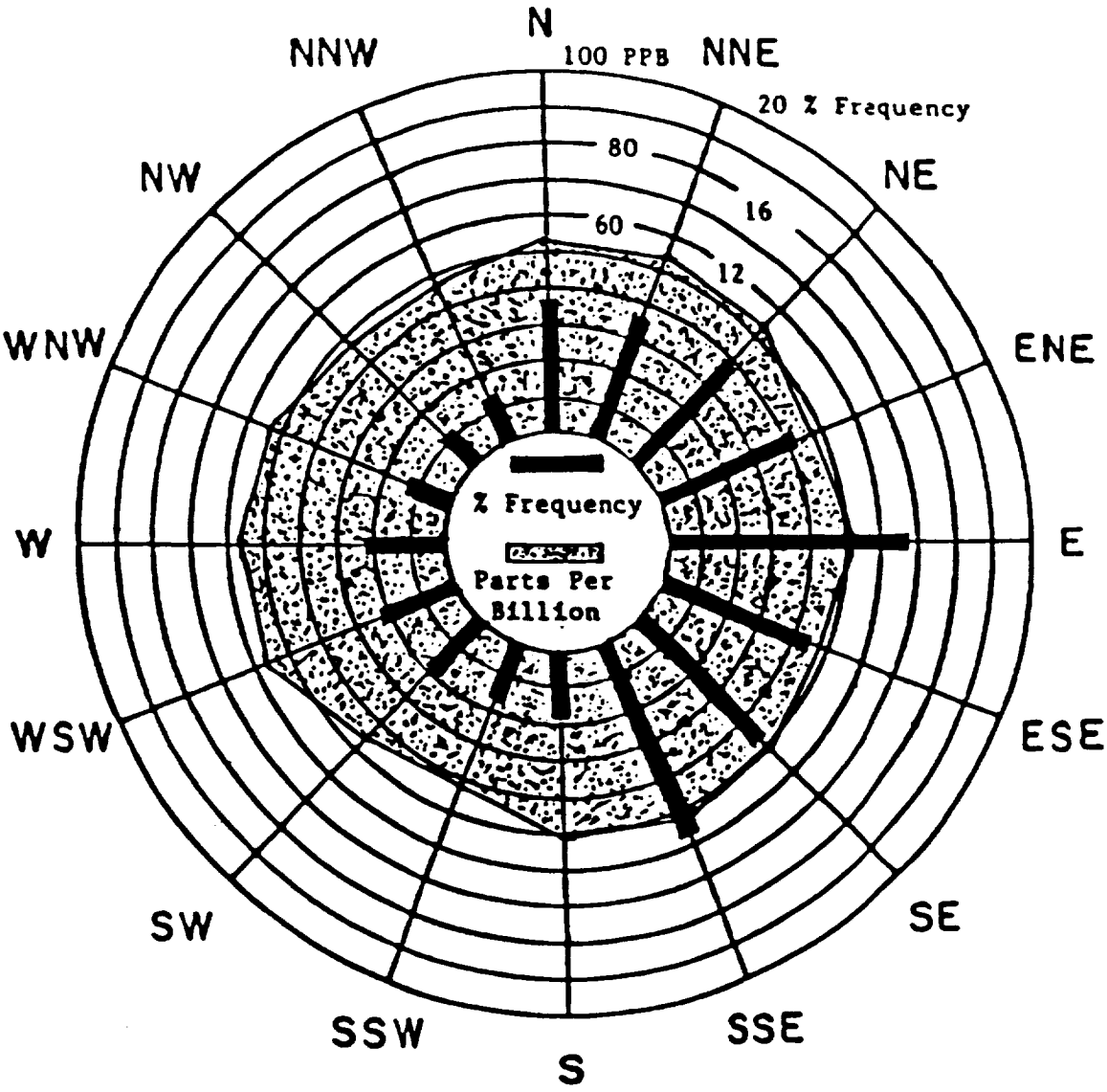
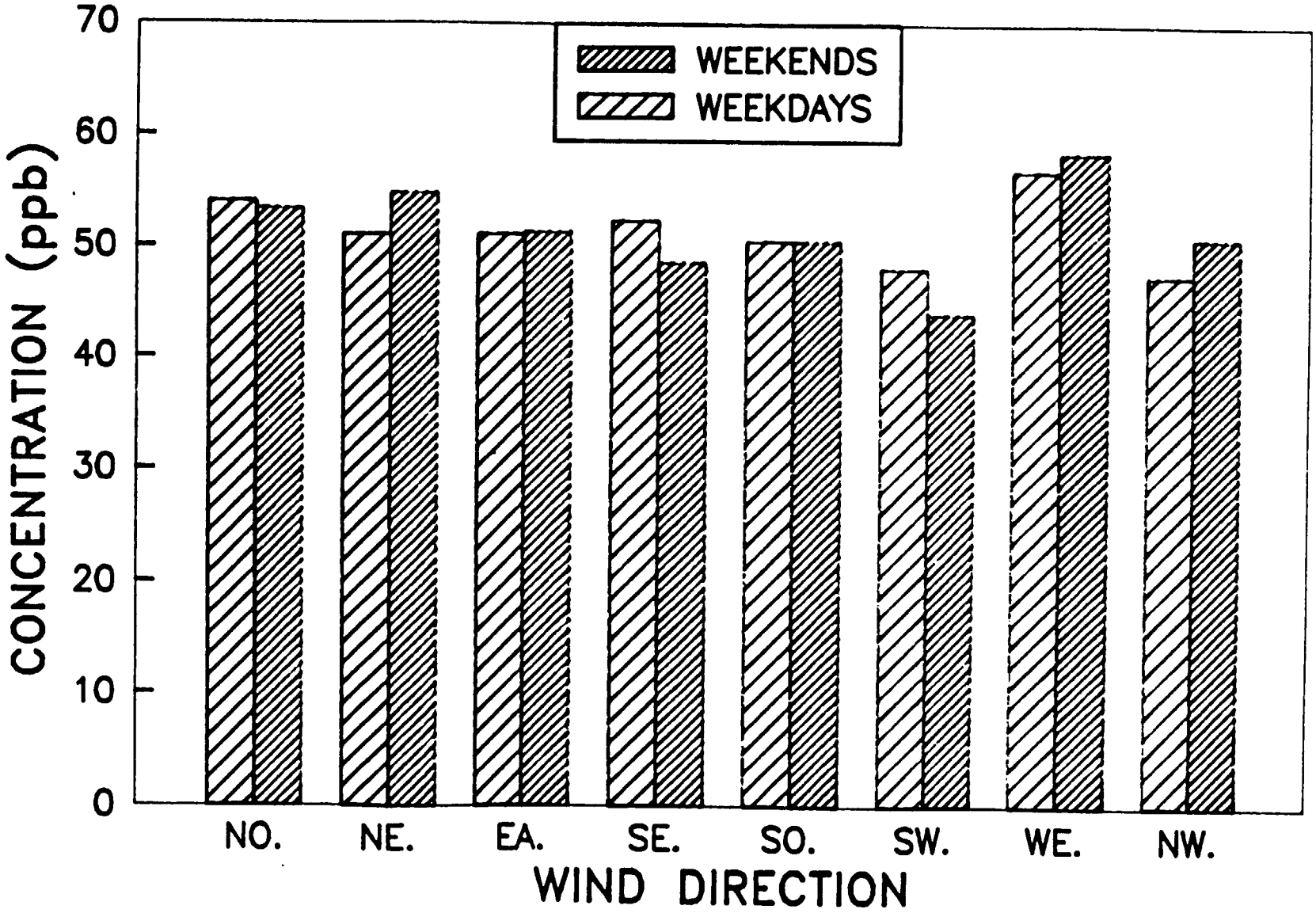


FIGURE 14
MEAN OZONE CONCENTRATION AT KSC BY WIND DIRECTION AND DAY



Special weather patterns are reported to play a dominant role in the occurrence of O_3 exceedances in Florida[5]. A double high (Gulf and Atlantic) scenario accounts for 87 percent of observed exceedances of the O_3 standard with the remaining 13 percent being attributed to a stationary frontal system. Even though there has not been any observed exceedances of the O_3 standard at KSC, the influence of weather pattern upon "high ozone days" (more than 80 ppb was investigated upon recommendation of Mr. Shao-Hang Chu (per comm.). Forty-one percent were associated with high pressure systems: "double high" = 33.2 percent, "triple high" = 2.6 percent, "Central Florida high" = 2.6 percent, and "Bermuda high" = 2.6 percent. Also, frontal patterns accounted for 48.7 percent of the high ozone days as follows: Gulf front = 23.1 percent, southeastern front = 20.5 percent, and a stationary front = 5.1 percent. The last weather pattern found was that of hurricane/tropical storm which accounted for 10.3 percent. The mechanism appears to be that as the low pressure cell impacts the Florida coast and begins to either travel up the coast line or proceeds inward, it "drags" an air parcel behind it which contains relatively high ozone (84 ppb).

CONCLUSIONS

1. The 24-hour SO_2 annual averages have decreased each year and even though the highest 24-hour SO_2 average at KSC was higher than most of the east coast, the second highest 24-hour SO_2 average was lower than the reported statewide nine-station averages for each year except 1983.

2. The NO_2 annual averages at KSC were much lower than the statewide nine-station averages for each year except 1983. There was a slight increase each year at KSC from 3.3 ug/m^3 in 1983 to 4.6 ug/m^3 by 1986.

3. The CO annual, second highest eight-hour, and second highest one-hour averages were lower than the statewide averages for micro-scale, middle-scale, and neighborhood scale.

4. The four years of PM_{10} samples reflect a range of 2.9 to 150.1 ug/m^3 with a mean and 95 percent confidence limits of 25.89 ug/m^3 and ± 2.68 ug/m^3, respectively.

5. Ozone maximum annual one-hour averages are consistently high compared to the federal and state standard of 120 ppb. It has increased yearly (98, 101, 103, 109 ppb) from 1983 through 1986.

6. An analysis of variance on the O_3 data from KSC indicated that there were no significant differences between months of the year, weekdays versus weekends, or wind directions.

7. An analysis of variance on the NO_2 data from KSC indicated that there was no significant differences between years but that January was significantly higher than the other months and that the weekdays were significantly higher than the weekends. Also, a weak correlation of 0.2182 was found between NO_2 and O_3.

8. Weather patterns are involved in the formation of "high ozone" days. Forty-one percent were associated with high pressure systems, 49 percent were associated with frontal patterns, and 10 percent were associated with hurricane/tropical storms.

In summary, the overall air quality at KSC is good, but future regional development may have an impact, and monitoring at KSC will be continued. Based upon the data analysis in this paper, it is recommended that the state air monitoring network for O_3 be expanded to include Brevard County.

ACKNOWLEDGEMENTS

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